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EFFECT OF METAL QUALITY AND GOB FEEDER BLADE DESIGN ON DEFECT FORMATION IN GLASS IN GOB CUTTING

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The optimum design and metal composition for gob feeder cutting blades that reduced blade wear, entry of metal products of blade wear into the glass melt gob, and decreased the defects that arise in gob cutting were determined.

In manufacturing television screens and monitors, glass insulators, optical instrument parts, and other items, it is necessary to increase the quality and smoothness of the glass surface. However, manufacturing these articles by extrusion inevitably causes defects in the glass at gob cutting sites: primary and secondary cutting track, whose existence is established by studying the surface layer of the glass even at comparatively low optical microscope magnifications (× 6 – 100) in transmitted light [1, 2].

Defective regions are observed in the zone of the primary gob cutting track: parallel, longitudinal, relatively large (approximately 0.2 mm), oval pits, sometimes even with microcracks on the edges; next to a chain of small gas bubbles; separate larger bubbles; longitudinal folds in the glass with altered chemical composition. Such defects at gob cutting sites were also established in cutting electrovacuum glass gobs (Fig. 1).

The secondary gob cutting track is less concentrated and coarse. This is due to drawing of the surface layer of glass with the secondary cutting track in it into the feeder eye when the plunger rises and partial melting of the cutting track in the hot glass melt.

Since the duration of the reaction of the secondary gob cutting track with the hot glass melt is from 6.5 to 12 sec (as a function of press output), after the glass melt flows out through the eye, the secondary cutting track becomes longer, thinner, and is almost totally melted. It should be noted that the primary track, from gob cutting to molding the article, only lasts for 3 – 4 sec in reacting with the glass melt.

Attempts were previously made to explain the causes of formation of glass melt gob cutting defects by the mechanical effect of the cutter blades on the surface layers of the glass when the cutting edge of the cutters moved back and forth and the temperature of the cutting edge metal dropped [3]. It was found that the chemical composition of the glass changes sharply in the region of gob cutting tracks. An increase in the amount of such chemical elements as tungsten, chromium, and vanadium, which were not part of the initial charge, in the defective zone indicates that products of wear of the metal in the form of microshavings enter the glass melt gob cutting zone. Hypotheses were also advanced about the possibility of crystallization of individual sections of glass with strongly altered chemical composition [1, 2].

The increase in the number of flaws in gob cutting simultaneously with the increase in metal wear due to friction of the blade – blade pair is in good agreement with the increase in wear of the cutting blades with the operating time of the cutters, but this is almost not correlated with the increase in the number of defects in gob cutting in the initial period of operation of new cutters.

The mechanism of formation of defects in glass melt gob cutting has not been definitively elucidated. Experiments with a modified section of the cutting cutters were conducted to determine the causes of the glass defects that arise in primary and secondary gob cutting zones (Fig. 2).

The essence of the change in the geometric shape of the cutting part was to significantly reduce the surface contact area of the blade – blade pair at the time of cutting the glass melt gob and thus as few products of metal wear formed in

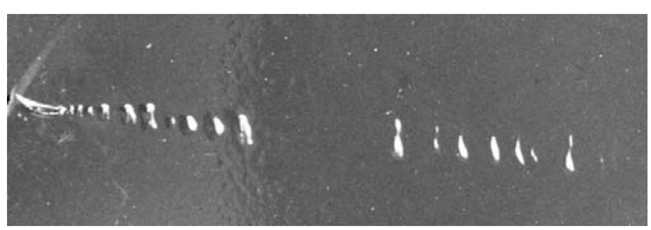

Fig. 1. Defects in electrovacuum glass in the primary gob cutting track zone.

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friction of the hot blades as possible would enter the cutting zone. For this purpose, the sliding surface of blades of the usual design was decreased by more than 3 times by removing the layer (height $h = 0.4 - 0.8$ mm) in direct contact with the blade pair, so that the initial thickness of the blades would only remain in a band with a width of $b = 10 - 12$ mm at the line of the cutting edge.

Such a change in the blade design has another advantage — it creates a layer of dry air which serves as additional thermal resistance in the path of propagation of heat flow from the blade edge line into the metal.

The blades were made of high-speed steel R6M5 designed for cutting in hot conditions.

Cutting defects in electrovacuum glass are usually eliminated in three stages. Coarse polishing of the surface of the glass with an electrocorundum suspension is conducted in the first stage, and the surface roughness after the first stage should not exceed 0.9 μm. The first smooth polishing is conducted with thick rubber disks using a suspension of softer polishing materials, pumice, for example. The surface roughness should be a maximum of 0.11 μm after the first smooth polishing and a maximum of 0.07 μm after the third stage of final smooth polishing, and gob cutting defects and easily detected ripple tracks should be totally removed.

The quality of defect removal in gob cutting to the standard level was established on a special detector bench. To determine the effect of the blade – blade friction surface area on the appearance of defects in gob cutting, the mass of the surface layer of the glass that had to be removed in polishing screens to the standard level was determined. The first series of screens (5 units) was prepared in gob cutting with cutters of the usual design and the second and third series (also on 5 screens each) were prepared in gob cutting with the experimental cutters.

As should have been expected, the defects, especially pits, grooves, and in the primary cutting track, were coarser in the first series of screens. It was necessary to remove 178 – 184 g of glass to remove them by polishing. In cutting the glass-melt gob with the experimental cutters, the defects in the glass were less pronounced, and only 112 – 136 g of glass had to be removed to reduce them to the standard level. This allowed significantly decreasing consumption of polishing materials, power, and the duration of the polishing operations. The data from the experiment confirmed that the amount of blade – blade pair friction wear products is very important in the appearance of gob cutting defects.

Another possibility for glass melt gob cutting defects in our opinion is correctly selecting the chemical composition of the cutter metal. Cutter wear and the possibility of heterogeneous crystallization in the glass cutting zones are directly correlated with the chemical composition.

At glass works, high-speed steels P18 or R6M5 are most frequently used for feeder cutters. High hardness, strength, and wear resistance are usually obtained by alloying the steels with tungsten, molybdenum, vanadium, and cobalt. In

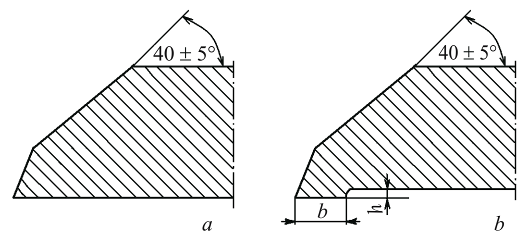

Fig. 2. Sections of glass melt gob cutting blades of ordinary (*a*) and experimental (*b*) designs.

addition, all high-speed steels contain 3.5 – 4.5% chromium. Tungsten and molybdenum carbides are the basic components of the steel that ensure high hardness ($HRC \sim 60$) up to 550 – 600°C.

Scarce tungsten can be replaced by less scarce molybdenum (especially since 1% molybdenum additive corresponds to approximately 2% tungsten additive), but when the amount of molybdenum in the steel is increased, its tendency toward decarbonization will increase. Decarbonization processes begin when the steels are heated above 700°C. In the decarbonized layer, which is 0.2 – 0.5 mm thick, two zones are usually formed: total and partial decarbonization. In the total decarbonization zone, the structure of the steel becomes purely ferritic, soft, and labile due to decomposition of secondary cementite, so that this zone is rapidly and easily subject to wear during operation of the cutters. In the zone of partial wear, the amount of stronger perlite flakes in the steel also decreases with a simultaneous decrease in the hardness, strength, and wear resistance. It was found that steels alloyed with molybdenum and silicon are decarbonized to the greatest degree in high-temperature conditions [4].

It was previously established in [5, 6] that on contact with the glass melt at the temperature of 1050 – 1100°C, the cutting edge is heated to 750°C. In addition, when steel is heated in air above 600°C, oxidation also takes place with formation of brittle oxide films on the surface layer. The study of the morphology of the cutting edge of the working cutter confirms that the metal in the front part of the cutting edge is strongly damaged and cracks appear due to decarbonization and oxidation processes.

The alloying molybdenum could be replaced by vanadium or cobalt to reduce the level of decarbonization of the metal in cutters designed for hot cutting. The vanadium in the steel forms very hard, strong, and stable carbide crystals, which increase the resistance of the steel to wear in high-temperature conditions. However, high-speed steels with a high vanadium content are difficult to process in fabricating cutters. Cobalt carbide also has a similar effect on preservation of the high hardness of steel in hot cutting conditions, but vanadium and cobalt, like tungsten, are scarce and expensive elements.

The amount of carbon is of no little importance for preserving the high hardness of high-speed steels with respect to decarbonization. For steels working at room or insignifi-

TABLE 1

Steel	Mass content, %						W_x, %
	C	Cr	W	Mo	V	Co	
R6M5 (control)	0.85	4.00	6.00	5.00	2.00	0.25	100.0
P18	0.78	4.10	17.75	0.50	1.20	0.25	88.1
P18K5F2	0.90	4.10	17.75	0.50	2.00	4.95	114.4
P9K5	0.95	4.10	9.50	0.50	2.50	5.50	100.5
P12F3	1.00	4.05	12.50	0.50	2.70	0.25	97.0
P9M4K8	1.05	3.30	9.00	4.05	2.50	8.00	139.4
T1	0.70	4.00	18.00	–	1.00	–	81.7
T4	0.75	4.00	18.00	–	1.00	5.00	95.0
T6	0.80	4.50	20.00	–	1.50	12.00	131.9
M6	0.80	4.00	4.00	5.00	1.50	12.00	123.1
M15	1.50	4.00	6.50	8.50	5.00	5.00	246.9
Z150 WKVC 12-05-05-04	1.50	4.00	12.00	–	5.00	5.00	155.8
Z165 WKVC 12-10-05-04	1.65	4.00	12.00	–	5.00	10.00	184.1
Z80 WKVC 18-10-04-02	0.80	4.00	18.00	–	1.60	10.00	119.7
Z175 WKVC 10-07-05-05-04	1.75	4.00	6.50	5.00	5.00	10.00	230.9

cantly elevated temperatures, a carbon content within the limits of 0.80 – 0.95% is close to optimum (approximately 1.10%). However, for high-speed steels cyclically heated to 750°C and higher, this amount of carbon is hardly sufficient. For this reason, the carbon content reaches 1.05 – 1.75% in many high-speed steels: 1.05% in P9MYK8, 1.50% in M15, 1.65% in Z165WKVC 12-10-05-04, and 1.75% in Z175 10-07-05-05-04.

The effect of the amount of carbon and other basic alloying elements is also seen from the empirical equation in [4], proposed based on statistical data for assessing the comparative wear resistance of high-speed steels:

$$W_x = 100 \times 1.173\text{C} \times 1.027\text{W} \times 1.027\text{Mo} \times 1.143\text{V} \times 1.029\text{Co},$$

where W_x is the relative wear resistance of high-speed steel of defined composition in comparison to a control, %; 100 is the wear resistance of the control steel (R6M5, for example), %; C, W, Mo, V, and Co are the differences in the amounts of chemical elements in comparison to the amount in the control steel, %.

This equation can be used to provisionally evaluate how the wear resistance of steel changes when it is replaced by another if the chemical compositions of both steels are known.

For comparing the effect of the chemical composition on the wear resistance, the values of the relative wear resistance of high-speed steels calculated with the above equation are reported in Table 1.

In analyzing the differences in the chemical composition of high-speed steels, we find that steels M15, Z150, WKVD 12-05-05-04, Z165 WKVC 12-10-05-04, and Z175 WKVC 10-07-05-045-04 contain a large amount of tungsten, vanadium, and cobalt alloying elements. They reduce the sensitivity of the steel to overheating and reduce loss of hardness at high temperatures. In comparison to control steel R6M5, the amount of vanadium in them is more than 2 times higher, and the amount of cobalt is 20 and even 40 times higher. These high-speed steels also contain much more carbon. As a result, their wear resistance increases by 1.5 – 2.5 times.

When the design of the cutting part of gob feeder cutters is altered and the chemical composition of the cutting instrument material is correctly selected, cutter wear can be reduced, the amount of products of metal wear entering the gob cutting zone can be decreased, the amount of primary and secondary glass cutting defects can be reduced, and process operations for polishing the surface of screens can be accelerated and made less expensive.

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